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AUTHOR	Hatton, Mary
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ABSTRACT

In order for students to experience science as scientists do, they must learn the skills of inquiry. This paper examines inquiry as a way of learning science and presents strategies to promote inquiry in teaching science. A model of progression of inquiry skills from grades K-2 to 3-5 is presented and the skills are aligned with the Massachusetts Science and Technology Frameworks. Several strategies, including mystery boxes, discrepant events, and use of the learning cycle to promote inquiry based on personal experiences, are discussed. (Author/SOE)

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Weaving Inquiry into Your Science Curriculum

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Mary Hatton
November 8, 2001
MAST Meeting
Worcester, MA

mhatton@endicott.edu
Endicott College
376 Hale St.
Beverly, MA 01915

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Introduction

Young children often describe what scientists do as, "discovering things, asking questions, and doing research." Inquiry is the process of science. It is a strategy that builds on the curiosity and interests of students and guides them to develop a deeper understanding of the world rather than just reading about it. According to the National Science Education Standards, "full inquiry involves asking simple questions, completing an investigation, answering the question, and presenting results to others."

As stated in the Massachusetts Frameworks, inquiry should arise within the curriculum and be integrated within the domains of science and technology. In order for students to experience "as scientists do," they need to learn the skills of inquiry also referred to as science process skills. The process skills are the focus of the early elementary years. These skills include questioning, making observations, predicting, using tools to collect data, and communicating information. These skills can be built upon in the later elementary years as students are expected to take part in designing investigations, which require them to utilize the process skills and more math skills to analyze and interpret data. In Figure1a, the progression of inquiry skills from K-2 to 3-5 is presented, based on the Massachusetts Science, Technology, and Engineering Frameworks. The right most column shows my variation of the cycle or process of science investigations with connections to various inquiry-related skills. This is also indicated in Figures 1b-c for the middle school and high school alignment with Massachusetts Science, Technology and Engineering Frameworks.

Inquiry is different from the 'hands-on' philosophy associated with many science kits or labs. The hands-on approach to science usually contains specific outcomes and results that students are supposed to successfully accomplish. There is emphasis on following the procedures when using science kits. The problem with this approach is that the child's role becomes limited to following directions to a pre-set investigation, rather than raising questions, making decisions, and choosing an approach to solving a problem. Students need to understand that science does not come from asking questions and reading a book; yet, our high school students believe this in practice.

Charles Pearce describes inquiry as a child's experience in the sandbox. In a sandbox, children do not follow directions or use specific materials for a particular activity. There are no predetermined results or restrictions based on another's agenda. The child is empowered, owning the discovery in the sandbox. Inquiry is a student-centered strategy or an approach to learning. Inquiry cannot come from a kit; it is in the "heads of students and teachers" as they construct meaning from materials from a kit or text (Saul and Reardon, 1996). Publishers create kits for the larger audience; they cannot include the background knowledge of what every child or teacher knows. For example, a student in Hawaii, lives around volcanoes, black sandy beaches, and tropical organisms. This experience is different from the New England student's rocky shores, seasonal changes, and animal hibernations. Inquiry allows one to connect what s/he knows and has available within the environment. Curiosity and interest with children arises from what they know, their surroundings. This is their background, just as scientists begin with interests based on their background knowledge.

Inquiry learning is related to constructivist philosophy, allowing student to construct knowledge and understanding. The skills of inquiry and investigations promote the development of higher ordering thinking such as application and synthesis of content. In addition, inquiry is a hands-on approach to open-ended questions or problem solving.

Variations of Inquiry Teaching

There are many variations in inquiry teaching; some inquiry-based activities are teacher directed, while others are student directed. Frequently activities that are labeled teacher directed inquiry are often no more than a hands-on activity. The teacher chooses the topic for investigation and students follow the teacher's directions to discover a topic. For example, "What is your pulse rate?" Everyone takes turns given the directions. Students reflect on what they learned. This is really a teacher directed, hands-on activity because the teacher developed the idea and all parts to the investigation. The outcomes and questions, prepared by the teacher, are directed toward a specific answer. The activity might finish with the definition of pulse / heart rate.

As an inquiry-based lesson, this activity needs to become more open-ended for students to develop their own opinions or decisions. I try to alter textbook / kit activities

to be directed or initiated by me but also open for student decisions and opinions. The approach is teacher-directed; however, there is room for student direction and decision-making. This activity becomes a co-directed activity; we learn together. One way I might take an activity like the 'pulse' example is to integrate a science process skill with the activity. For example, upper elementary and middle school students should understand how to carry out and design an investigation. One skill they need to develop is data analysis. Activities that demonstrate patterns can be used to practice data analysis. Although this activity was to determine heart rate, partners may or may not have a similar pulse rate. And some may develop a misconception that what the measurement of their own pulse rate is consistent with everyone else in the room. Looking at the whole class of data would allow one to do some math, such as a discussion of averages, range, or other basic statistics. I have done the following with this activity; we notice some differences in the students' information and begin to brainstorm reasons for those differences. I just pose the question, why? Students brainstorm, discuss in small groups, and report for a whole class discussion (Think-pair-Share).

This type of activity has led to a whole-class discussion about many variables, such as taller students / heavier students / students who had been standing vs. sitting while their pulse was being taken / students that had been running around at recess, etc. Then as a group, we looked at the ideas together and developed a teacher/student co-investigation. We might explore one idea as a class or groups of students may choose a variable and conduct the experiment, collect information, draw some conclusions, and share their results and conclusions in the last class. The sessions that follow this activity might begin a unit on the heart and circulatory system. In order to develop inquiry with students; however, they need to have more freedom for their own work and decisions. Students in this situation brainstormed/hypothesized/and predicted reasons for variability in data. They learn to consider variables and develop ways of testing them, observing on their own, collecting data and drawing conclusions. Reorganizing the pulse activity took 2-3 (60 minute) sessions. If time were an issue, which it can be, I might focus on drawing conclusions and predicting possible theories for differences from the data and stop the activity. In addition, you could have students develop a written proposal for an experiment, similar to the open-ended questions from the MCAS tests. This activity

progressed from being teacher-directed to more co-directed because the students develop their own ideas. And I would revisit this exploration throughout hands-on activities and discussions during the unit. The students should develop a deeper understanding because they have an experience to relate to, an experience that they were not only engaged in but also empowered.

In some cases, however, I have had a discussion with classes about pulse and circulatory system and used this type of activity, listed above, as a way of having the students apply what they learned in class. In this case, I would assess their conclusions from 'patterns of whole class' pulse data and require their hypotheses to include concepts learned from class.

Another type of inquiry project that I have explored has been a student-developed investigation. From one of my middle school experiences, I developed a year-end performance assessment project that required students to choose a consumer product, develop their understanding of experimental design, and apply their project to science content from the curriculum. One pair of students tested the effect of skittles on heart rate. They were curious to see if the sugar would affect one's pulse. They designed their own investigation, using the concept of heart rate and demonstrating their understanding. I have integrated this type of project at the middle school level. The students developed an understanding for process skills or and methods of inquiry throughout the school year. I took lab activities or problems and revised them so that an additional objective was a process skill or aspect of the scientific method. As a result, students built upon their understanding of skills during the semester. An example of the course schedule and integration of skills is attached. The students were truly scientists as they worked on this project.

How does one implement inquiry? There is no single correct way to incorporate inquiry into the classroom. It can be presented in different forms. I recommend that a teacher begins to implement inquiry with a lesson or topic that is most familiar. And try one or two in the first year and expand upon it over the next years. Also listen to the students. What are they curious about; or what questions do they pose when discussing in groups? Record them and use them the next year.

Strategies to promote Inquiry

There are several strategies that can be used to promote students to develop their own investigations. Students need to develop process skills at early ages in order to become independent enough to develop their own investigations. As I mentioned, I often look at a hands-on activity and try to readjust it so that the students are developing and carrying out their own testing. I would like to share some additional practical methods for beginning inquiry experiences with students. As this section progresses, inquiry skills from the Massachusetts Science and Technology Frameworks will be mentioned.

Mystery Boxes

Another strategy might be to create mystery boxes or discovery boxes as science centers at the elementary level. This might range from having one mystery box per unit to having a day/session of many investigation boxes on several different science topics. These boxes could be designed for any level of student. They could be organized for independent work or could be designed for small groups. Rather than giving students a whole set of directions with a lesson you perform in one of your kits, you could give the students no directions, just the contents of a science kit in the hands of students. Give the students the topic to explore or the problem and have them develop their own investigation using the materials provided. However, if students explore and develop their own investigation, the students need some background or prior knowledge to build upon. A teacher may then present students with simple hands-on questions to answer/explore with the materials that provide them with enough prior knowledge to develop a testable question. For example, Figure 2 (below) shows a possible set of background experiences that a student could use to develop an understanding of sinking and floating that would lead to more curiosity and a student-developed investigation. Another alternative would be to have students learn background information and then explore the box of things.

The mystery boxes engage the learner and allow the learner to build on prior knowledge through hands-on activities. The teacher may or may not decide to have students record answers to these questions. The questions provide an opportunity for all students to develop some prior knowledge and inspire new questions and ideas the

student has added to prior knowledge. Additional details about mystery boxes can be found in the work done by Charles Pearce (1999).

Discrepant Events

Another way of initiating an inquiry-based activity at the start of a unit is presenting a discrepant event. A discrepant event is something that students can observe and find puzzling; the idea is that this puzzling situation stimulates the student to develop questions or thoughts about a situation. For example, the following is a discrepant event that relates to a lesson on density. A discrepant event, which could be presented before beginning a lesson, might be a raisin in water activity. Two glasses of water could be prepared, one with salt water and one with freshwater. Place a raisin in each glass. Ask the students to make some observations and predictions about why they might observe differences? This could lead to many ideas ranging from different substances in the two containers to trying additional raisins/same raisin in the containers.

When using a discrepant event, students have to use process skills. For example, in the presentation of the raisins, they are using their observation skills and making predictions or raising new questions. In the preK-2 levels, "asking questions" is mentioned and in the 3-5 level, "predictions that are testable" are used. Learning how to ask inquiry-oriented questions leads to an understanding of hypothesis. Inquiry-oriented questions or questions that lead to scientific inquiry are sometimes referred to as testable questions. There are two general categories of questioning: testable questions, which require an experiment, and research questions, which require one to read and write a report. Testable questions are inquiry-oriented questions.

Asking Questions

In the early elementary years, it is important for students to learn the difference between these types of questions. One way to encourage students to develop their own questions is to have them focus on their observation skills. For example, if they are given an object, they might be required to sketch it, describe it using their senses, share their observations with others and then list as many questions as they can think to ask about the object. Through a class discussion, someone always mentions 'doing' something to

answer a question. From the class questions, the students can, together, categorize questions as testable or not testable. In addition, students can also discuss how or what types of investigations / tests could be done on the object. As a teaching tool, this could be modified as a prompt to use as part of a discrepant event. This is a useful way of having students write their ideas and a way to assess their understanding. Examples of prompts can be found in Pearce, 1999.

If students are developing an investigation, there are additional ways of helping the students to refine their testable questions and reflect on different aspects of the inquiry process. The best way for students to learn how to question and develop an investigation is for the teacher to model questioning in the classroom. I like to introduce different aspects of investigation, which allows me to help students develop questioning skills and focus on developing an understanding about the process of science. Figure 3 contains a listing of some guiding questions teachers could use to assist students in reflecting on the process of investigating. The questions are grouped according to various parts of the investigation process and are consistent with inquiry skills described as part of the Massachusetts Framework in Science and Technology, which is show visually in Figure 1a-c. These activity sheets are useful at any grade level. Although, at the fourth and fifth grade levels, students should not need these prompts, if teachers are working on questioning and predictions with students throughout each grade level.

How do you have students generate questions? How do you pick out engaging questions for an investigation? The students come up with some amazing questions. I have learned to maintain a list of testable questions, which I might introduce in up coming years. I used to feel guilty when students came up with good questions and I was on a time limit. I still feel this way at times. Another method is developing a 'Question Board' in the classroom. There might be a special time during the day, in which students contribute a question to the board. The questions might be revisited and analyzed at another time during the year. This could change as students progress through a unit and revisit the questions at the close of each unit. I do this using science journals and revisit at the end to have students apply their understanding from what they learned in class. In addition, this method gives me some insight into conceptual understanding of students

and their growth. I might find a testable question to incorporate into the unit. And this list of questions may provide new investigation questions for the coming years.

Other Inquiry Skills

In addition to developing testable questions and predictions, the Massachusetts Science and Technology Frameworks emphasize that grades 3-5 should be able to "keep accurate records while conducting a simple investigation". This skill implies that students should become more independent and responsible as they become engaged in an investigation. This is a skill that can be practiced as teacher-directed inquiry throughout the curriculum. For example, with the pulse activity, the students could develop a way to organize, collect, and present data. In grades 2-3, the students should begin to develop these skills or an understanding of various aspects of these skills. As students develop their own independence for keeping accurate records, activity prompts can be used. For example the teacher may direct students to organize the questions they are answering, the date, and have a section to organize a sketch, explain what they did (methods) to answer the question, and mention their discovery from that day. An example is found in Figure 4. Whenever I introduce this type of method, I take time to explain why we are using this type of prompt. It is worth having a discussion about how scientists organize their information during an investigation and to discuss why many of these pieces are important. When I have this discussion, I find it helpful to relate this to an activity we've already done or an activity that students might have done the previous year – such as observing the caterpillar. Why were certain items important and helpful, what would happen if you hadn't kept track of this information. Of course another alternative is to have students do a simple investigation and then discuss the significance of recording data and coming up with a method. This prompt could be used at any grade level. I have seen many variations of this.

Personally, I address recording information as part of a whole class investigation and we brainstorm important aspects together as a class and these become the requirements in the science journal. This approach, I described, could be taken at the 4-5th grades, using the prompt as background. I find this prompt also useful because it has students create sketches, and describe what they did. As students progress from 3-5th

grade, they need to learn how to "extend observations and make measurements using scientific tools". This prompt allows for modifications, such as adding a section for students to mention and explain what tools they used. These two aspects of collecting and recording data also imply quantitative and qualitative observations. Although graphs and tables are not mentioned, these skills should also be included as part of the investigation process.

Management

When teaching during an inquiry activity, it is important to circulate from group to group. It is good to listen to conversations and reflect on what students are doing – do they have a plan? Are they able to explain what they are doing? What is intriguing them? The teacher's role is to be available to listen, assist when asked, and locate any additional materials that might be needed. Lawson (2000) has developed a list of practical means of dealing with students while implementing inquiry-based techniques. These are practices that we are all aware of; I find it useful once in awhile to refresh my memory.

Assessing Inquiry

Assessment during an inquiry-based project or investigation is a continual process. Some pieces of assessment may be used to guide the teacher in planning. For example, assessing students on their understanding of variables might be a formative assessment early on before an investigation and it may also be part of a summative assessment at the end of an investigation. The formative assessment would provide the teacher with information about the students' progress in understanding a concept. I personally use checklists both formal and informal; however, an investigation also can be worked into a rubric, as shown in Figure 5a-b. There are two rubrics presented; one focuses on the journal and the other on the final investigation, which might be a report. The journal usually does not become part of the final report; however, it contains all the ideas, collection of data, and reflective thoughts of the students.

Balancing Content and Inquiry

A teaching strategy that I like to use, which helps me balance content and inquiry, is the learning cycle. J. Myrin Atkin and Robert Karplus developed this strategy in the 1960s. The cycle is based on Piaget's developmental theory and the process of constructivism. This method allows students to develop their own conceptual understanding and construct knowledge through problem solving situations. The learning cycle contains five phases: engagement, exploration, explanation, elaboration, and evaluation. These steps could be done over the course of a unit or in the course of a couple of days, depending on a lesson/unit.

The first phase of the learning cycle is called **engagement**. During this phase, the student focuses on a problem or situation. The activity should make connections between past and present learning experiences. This could be learning experiences that was previously taught. This is a technique that leads to building on students' prior knowledge. Asking a question, showing and defining a problem, or showing a discrepant event are some examples of ways to engage students to focus on a task. This technique also allows the teacher to preassesses student understandings about a concept, process, or skill. The role of the teacher is to present the situation and identify the instructional task. Students should be puzzled, ask questions, and be motivated from the activity.

When the students are engaged, they need time to explore their ideas. The **exploration** phase consists of activities, which should be concrete experiences that begin to build upon process skills and concepts. The students experience activities that the teacher can use later to formally introduce concepts, a process, or skill. During exploration, the students will develop process/inquiry skills such as observing patterns, questioning events, test predictions/hypotheses, and form new predictions and hypotheses, or record observations. The teacher's role during this phase is that of a coach or facilitator to listen and guide students, not to give directions and instructions. The teacher may ask probing questions to redirect students to the task at hand. This aspect of the learning cycle is / can be an inquiry / investigation.

Following the exploration, the teacher and students spend time **explaining** and using terms/vocabulary common to the concept. The teacher focuses student attention to specific aspects of the engagement and exploration activities. First, the students are asked

to give an explanation in their own words as well as justification for their explanation. This requires the students to relate their explanations to the exploration. Students draw conclusions based on evidence. The teacher should take student explanations and build on them to provide the scientific explanations in a direct and formal manner. The purpose of this phase is to have students learn to organize their exploratory experiences and have the teacher formalize their explanations and experiences with definitions, explanations, and/or new labels. The teacher bases her/his discussion on the students' explanations and connects these to the experiences from the exploration and engagement phases. This part of the learning cycle is teacher-directed.

Once students have an explanation for their exploration, the students are given time to elaborate or extend their understanding of concepts, processes, or skills. At this time, the students should use the formal labels, definitions, and explanations. This phase is called **elaboration**. Some students may still have alternative conceptions; this phase allows students additional time and experiences. One may have students work cooperatively to express their understandings. Students become involved in new experiences that require them to apply and extend their understanding from the explanation and exploration phases. The teacher refers students to existing data and evidence from their explorations.

The last part of this cycle is the **evaluation** phase, an opportunity for students to obtain feedback on their explorations. Assessment includes students being able to apply new concepts and skills, looking for evidence that students have changed their thinking or behaviors, students assess their own learning, asking open-ended questions. Educational outcomes should be assessed. This can be formal or informal assessment of student understanding. This part of the cycle could also be tied in with the elaboration phase.

Example using the learning cycle

Previously a discussion about 'sinking and floating' was used to illustrate an inquiry teaching strategy using a mystery or discovery box. The discovery box was described as an inquiry-based activity and investigation that could be done at a learning center, individual learning. However, this could be re-organized to fit into the learning cycle. For example, a teacher could ***engage*** students or groups of students with the

objects. The teacher could ask that the students about properties of matter they've learned from previous years or that the students had explored earlier in the year. The teacher might mention the idea of mass or volume/space. What do you know about floating? Have students open a bag/box or come to the room to get a box of objects. Ask the students to predict "Which of the different types of objects do you think will float or sink? How could you find out?"

From this initial activity, the teacher could guide the students to the ***exploration*** phase by having students explore the properties of different matter. The teacher could let it go from there or use prompts such as "Why do you think some objects sink while others float?" How would you create an object that could float!"

Following the exploration, the teacher can ask the students for an ***explanation*** about how the floating or sinking works and build on the students' explanations by using formal terms like magnetic fields or poles, like and dislike poles.

Elaboration might entail the teacher asking students to predict and explain what would happen if you "placed the large superball and small superball in the water?"

Evaluation might entail some scenarios that require an explanation and use of concepts discussed through the lesson. Predict, which will sink or float? Predict, how you could make a marble float?" students might have to explain and demonstrate the reason why.

Final Thoughts on Strategies that Promote Inquiry

I shared some of my personal experiences and explained different approaches I have used or found informative. I look at the hands-on activities that I use and try to create a teacher-directed inquiry experience from them. In doing so, I may tend to focus on a particular process skill. I try to do this with 1-2 hands-on activities per unit. I have also learned that the best inquiry experiences come from student questions, which is still difficult at times. I do try to have a student-directed investigation at least once in a year. I have found this to be most manageable for me personally. It is important for you to develop your own sense of comfort and trust with students and inquiry.

Although I have mentioned some guidelines on inquiry strategies, the best inquiry-based lesson evolves from the ideas and curiosity of the students. It is scary

because students gain learning/teaching responsibilities but it is amazing. And as the teachers, we lose control and enter into the unknown with our students. It is most beneficial to interact with colleagues who are also interested in inquiry-based teaching. It is important to listen to this side of them. For example, one of the most rewarding experiences evolved through a discussion about whether or not all living things, like plants, move. We had a long discussion and debate and the students found that they had different views about the concept movement. I automatically found myself saying, well there's only one way to find out, we need to prove it. I had 5 groups with different ideas and approaches to the problem. Their homework was to come up with a hypothesis and some ideas. They had time to develop ideas and methods in class. I previewed their proposals as they set out to organize their experiments. When they came into the classroom for the entire month, they immediately went to see their plants.

It is also important to not lose sight of the fact that your students need to develop an understanding of science, which is a balance between inquiry and content.

Inquiry Resources For Teachers

Baxter, Louise and Kurtz, Martha (2001). When a hypothesis is not an educated guess. Science and Children. April: 18-20.

Diffly, Deborah. (2001). Project reptile. Science and Children. April: 30-35.

Haines, Lonnie. (1997). Consumer testing: Applying the scientific method to everyday life. Science Scope. September: 34-38.

Haury, David. L. (1993). Teaching science through inquiry. ERIC document EDO-SE-93-4

Keller, David and Holden, Pamela. (1994). Science Guides Consumer Choices. Science and Children. Nov/Dec. 20-23.

Lawson, Anton E. (2000). Managing inquiry in the classroom: Problems and solutions. The American Biology Teacher. 62 (9): 641-648.

Pearce, Charles, R. (1999). Nurturing inquiry: Real science for the elementary classroom. Portsmouth, NH: Heinemann.

Pheeney, Pierette. (1997). Hands-on, minds-on. Science Scope. September:30-32.

Pierce, W. (2001). Inquiry made easy. Science and Children. May:39-41.

Saul, Wendy and Reardon, Jeanne, (Eds.). (1996). Beyond the science kit: Inquiry in action. Portsmouth, NH: Heinemann.

Schack, Gina D. (1994). Involving students in authentic research. Educational Leadership. 29-31.

Other Related Resources

A discussion about the learning cycle

Atkin, J.M. and Karplus, R. (1987). Discovery or invention? The Science Teacher. 29: 45-51.

Excellent resource text for examples, problems, and definitions of science process skills

Gabel, Dorothy L. (1993). Introductory science skills. (2nd ed.). Illinois: Waveland Press, Inc.

Figure 1a Inquiry PreK-2

Inquiry 3-5

Investigating

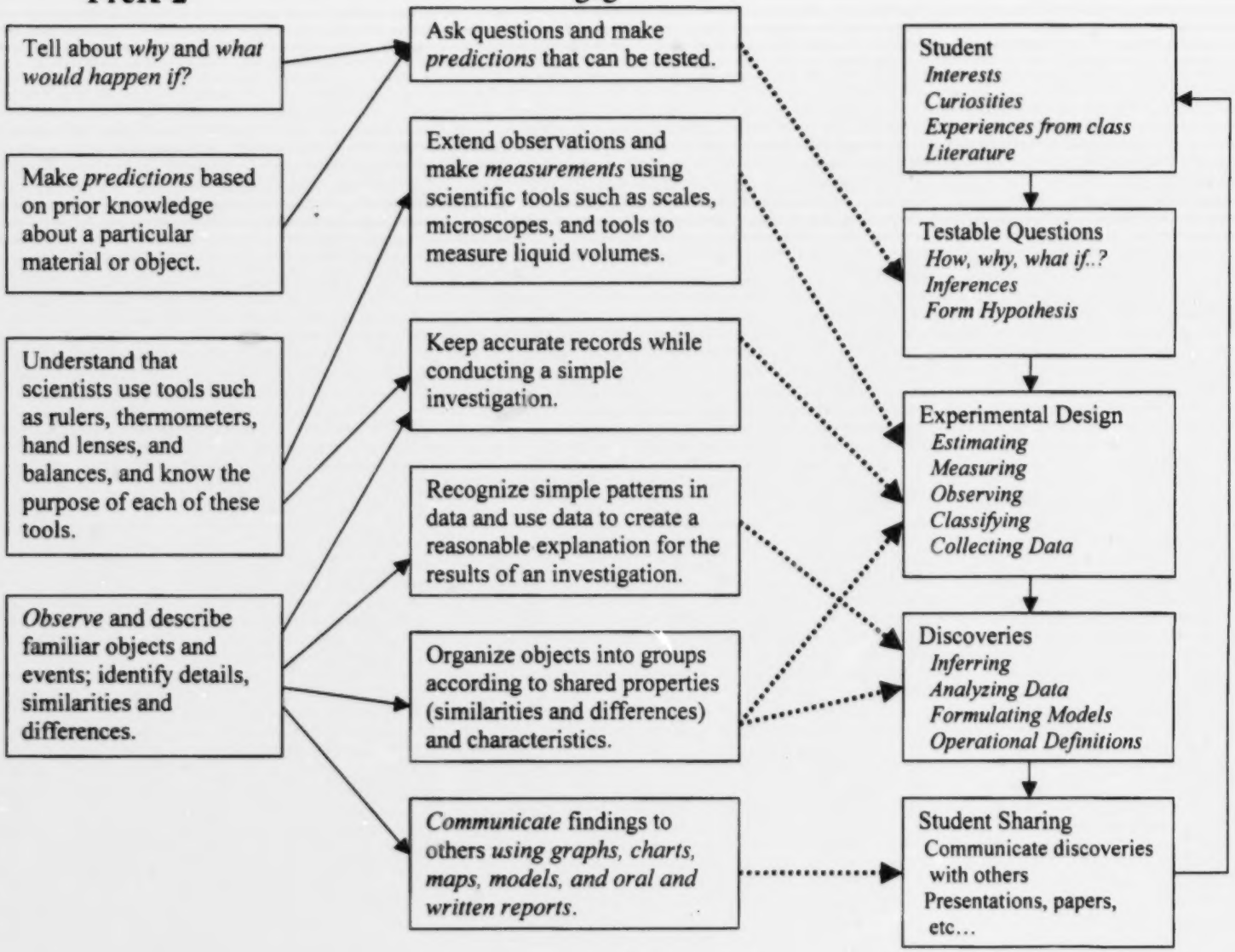
Tell about *why* and *what would happen if?*
Make *predictions* based on prior knowledge about a particular material or object.
Understand that scientists use tools such as rulers, thermometers, hand lenses, and balances, and know the purpose of each of these tools.
Observe and describe familiar objects and events; identify details, similarities and differences.
Ask questions and make *predictions* that can be tested.
Extend observations and make *measurements* using scientific tools such as scales, microscopes, and tools to measure liquid volumes.
Keep accurate records while conducting a simple investigation.
Recognize simple patterns in data and use data to create a reasonable explanation for the results of an investigation.
Organize objects into groups according to shared properties (similarities and differences) and characteristics.
Communicate findings to others *using graphs, charts, maps, models, and oral and written reports.*
Student
Interests
Curiosities
Experiences from class
Literature
Testable Questions
How, why, what if..?
Inferences
Form Hypothesis
Experimental Design
Estimating
Measuring
Observing
Classifying
Collecting Data
Discoveries
Inferring
Analyzing Data
Formulating Models
Operational Definitions
Student Sharing
Communicate discoveries with others
Presentations, papers, etc…

Figure 1b

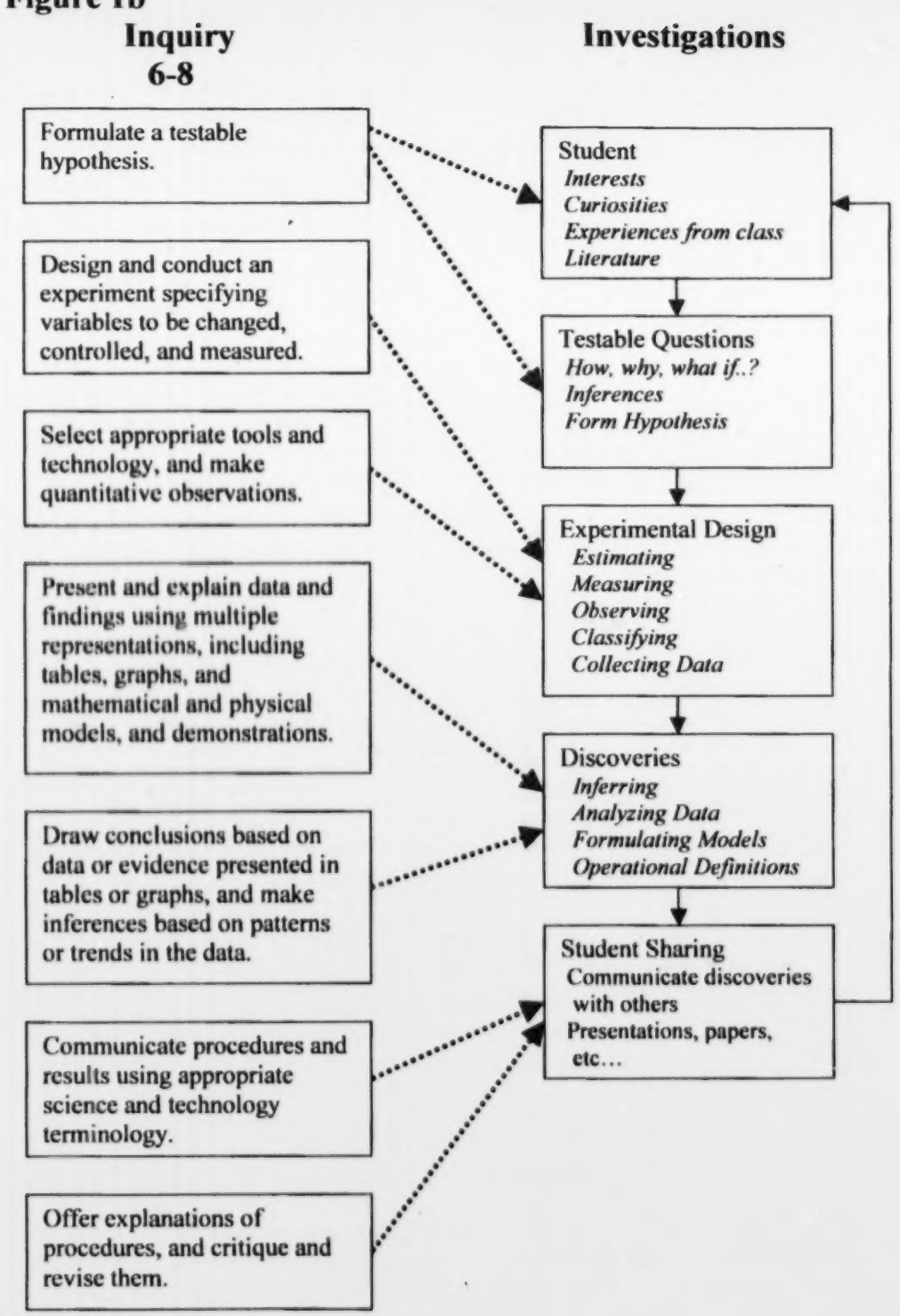
Inquiry
6-8
Investigations
Formulate a testable hypothesis.
Design and conduct an experiment specifying variables to be changed, controlled, and measured.
Select appropriate tools and technology, and make quantitative observations.
Present and explain data and findings using multiple representations, including tables, graphs, and mathematical and physical models, and demonstrations.
Draw conclusions based on data or evidence presented in tables or graphs, and make inferences based on patterns or trends in the data.
Communicate procedures and results using appropriate science and technology terminology.
Offer explanations of procedures, and critique and revise them.
Student
Interests
Curiosities
Experiences from class
Literature
Testable Questions
How, why, what if..?
Inferences
Form Hypothesis
Experimental Design
Estimating
Measuring
Observing
Classifying
Collecting Data
Discoveries
Inferring
Analyzing Data
Formulating Models
Operational Definitions
Student Sharing
Communicate discoveries with others
Presentations, papers, etc…

Figure 1c

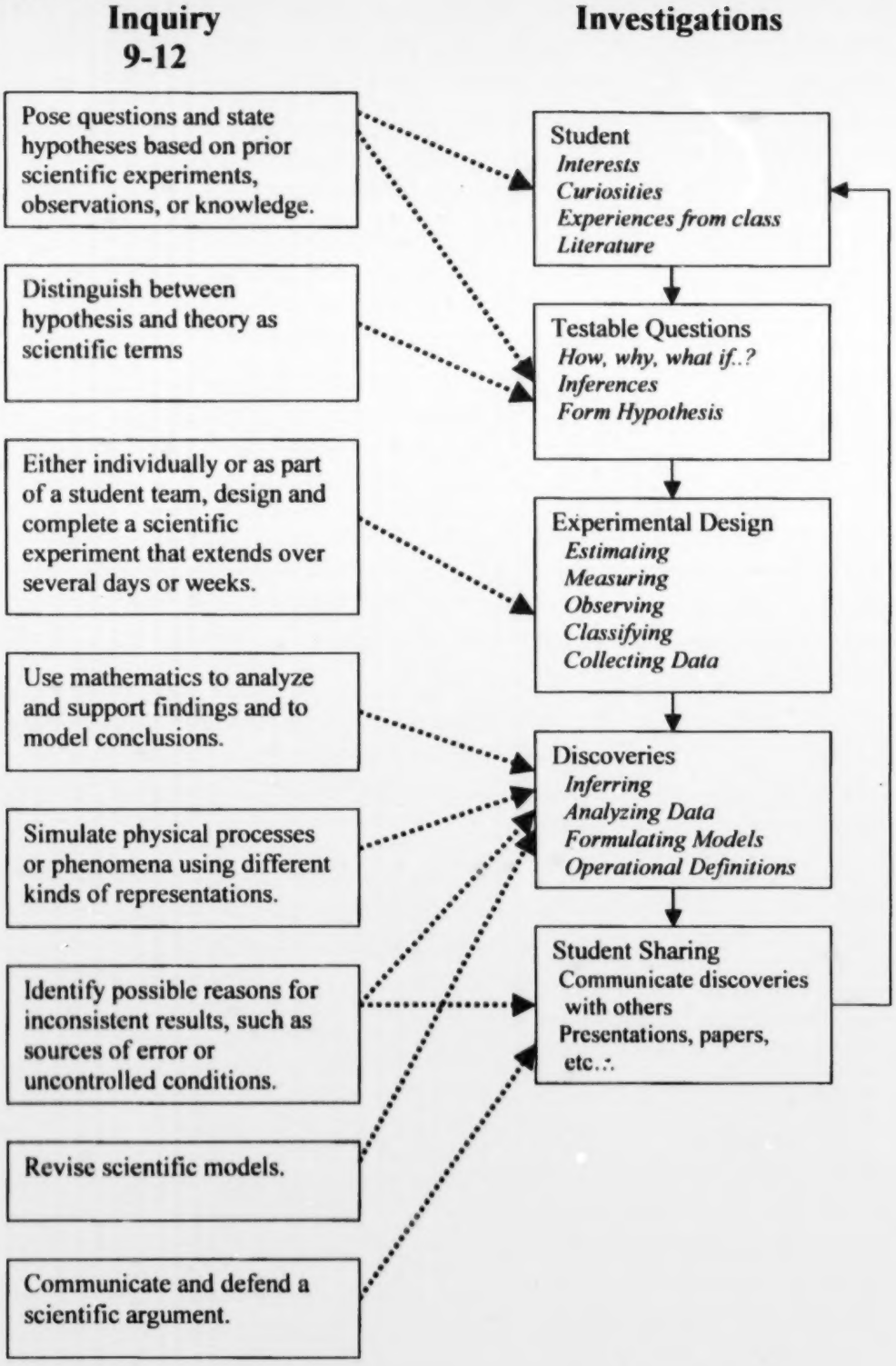
Inquiry
9-12
Investigations
Pose questions and state hypotheses based on prior scientific experiments, observations, or knowledge.
Distinguish between hypothesis and theory as scientific terms
Either individually or as part of a student team, design and complete a scientific experiment that extends over several days or weeks.
Use mathematics to analyze and support findings and to model conclusions.
Simulate physical processes or phenomena using different kinds of representations.
Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.
Revise scientific models.
Communicate and defend a scientific argument.
Student
Interests
Curiosities
Experiences from class
Literature
Testable Questions
How, why, what if..?
Inferences
Form Hypothesis
Experimental Design
Estimating
Measuring
Observing
Classifying
Collecting Data
Discoveries
Inferring
Analyzing Data
Formulating Models
Operational Definitions
Student Sharing
Communicate discoveries with others
Presentations, papers, etc..:.

Figure 2 Mystery Box Example

Sinking and Floating

Examine the different objects.
Which objects do you think are bigger in size?
Which objects are bigger in mass?
How can you find out?

Which objects do you think might sink?
Try placing each one separately in the bucket of water.
What happens?

There are two pieces of foil. Can you make one piece float and one sink?

Try it!
Could you develop a way to make any of the objects that went under the water float better?
Try some other ideas of your own!

Figure 3. Questions to Guide Students in Inquiry Investigations

During an investigation the teacher needs to encourage reflective discussions among students in order to develop an understanding about the process of inquiry. The following consists of a brief list of some examples of questions that I have found useful when working with various aspects of inquiry skills and investigating. The questions are not meant to be limited to the types of categories listed below. These types of questions could be posed to individuals, groups or a whole class:

General Types of Questions
Who agrees or disagrees with than explanation?
How can you rephrase the answer?
Who has another idea?
How does your answer differ from his answer?
What if…?

Various Components of an experiment/investigation – You may need to guide students to pose 'testable' questions, focus on their methods
What is the experiment about?
Do you need to define or set limit?
What are the variables (constants)?
"Can you find a way to…?"
"Can you make a sinking object float?"
"Can you make a plant grow sideways?"

Observations/Results – You may need to guide students about measuring, focus in on details by using their senses, or comparing their ideas
How did you organize the information?
Would a diagram or sketch help?
"Have you seen…?"
"Do you notice…?" followed by "What is it?" What does it do?" What do you see, feel, hear?"
"How many…?" "How long…?" and "How often…..?"
"In how many ways are these seeds alike and how do they differ?"
"Is this longer, stronger, heavier, more ___ than…?"

Analyzing Data
Ask questions that promote thinking about strategies and relationships?
Is there a pattern?
How is this alike or different from…?
What type of explanations can you make? Followed by "Why?" "How do you know?" "What do you think about ___?" "Why do you think….?"

Guiding Students to Develop Conclusions – helping them to reason out an idea, draw inferences,
Why do you think so?
What's wrong with…?
Would another method work as well?
How would you restate that in simpler terms?
Which words are most important?
Is that conclusion reasonable?
How do you know you're finished?

Figure 4 Journal Prompt

Today is _____

Our Investigation Question / Problem is

Our prediction/hypothesis is if……..then…….

Sketch from our observations

We observed…

_____

_____

_____

_____

_____

_____

_____

_____

Conclusions from today

The relationship between the manipulated and responding variables was....

My results are like or different from the prediction/hypothesis we made today because

My new questions for today are

Other Notes

Figure 5 Examples of Rubrics for Investigating

a. Scoring Rubric for Frog Investigation Journal

Scoring Criteria	4	3	2	1
Followed directions and completed activity				
Drew tadpole stage and labeled all external parts				
Drew froglet stage and labeled all external parts.				
Drew frog stage and labeled all external parts.				
All observations present with detailed descriptions				
Showed all measurements with proper metric labels				
Constructed graph to show growth changes in frog stages				

b. Scoring Rubric for Science Process Skills/Science Investigation Report

Scoring Criteria	4	3	2	1
Clearly stated questions				
Clearly stated predictions				
Data organized and neatly presented				
Data represented in chart or graph				
Description of plan				
Explains the use of materials and equipment				
All variables are identified				
Stated conclusion about the relationship between manipulated variable and responding variable				

4 points	correct, complete, detailed
3 points	partially correct, completed detailed
2 points	partially correct, partially complete, lacks some detail
1 point	incorrect or incomplete, needs assistance

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Organization/Address: Endicott College, 376 Hale St., Beverly, MA 01915	Telephone: 978-232-2336 FAX: 978-232-3100
	E-Mail Address: mhatton@endicott.edu Date: 8/30/03

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